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Mathematical Analysis and Simulation of Permanent Magnet Synchronous Motor for Electric Vehicle Application

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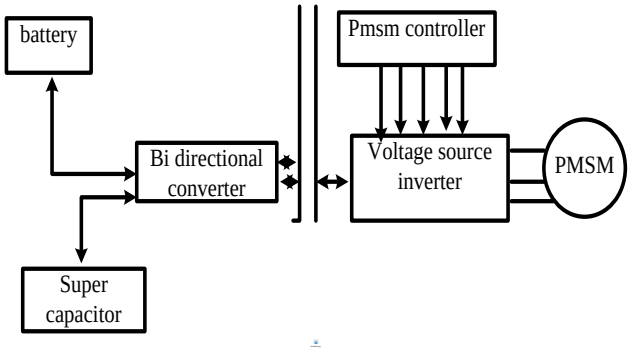
Abstract: ***Permanent magnet synchronous motors in electric vehicles are gaining more and more attention because of its high performance and high torque to inertia and high power density. PMSM Motor should operate in four quadrant operation at different driving characteristics the torque speed characteristics of the motor is observed. Battery and super capacitor is used for energy sources to the permanent magnet synchronous motor the design of electric vehicle is onboard charging system. Battery and supercapacitor are hybrid energy sources. PMSM motor is controlled by using field oriented control technique. Voltage source inverter is used to control the speed of the PMSMS motor at different frequencies. The control technique used for VSI is space vector control technique. Using MATLAB/Simulink.***

Keywords : EV, PMSM motor, PMSM mode.

I. INTRODUCTION

permanent magnet synchronous motor is same as the conventional synchronous motor only the difference is it consists of permanent magnetic the rotor so the field winding is absent in PMSM motor. PMSM is gaining of permanent magnet the losses in the motor are negligible. The controlling of PMSM is easy compared to the other motors. PMSM for electric vehicle application to drive the vehicle at different driving characteristics during motoring mode the torque and speed are positive and during regenerative braking positive speed and negative torque in this mode the load act as a source to the vehicle.
Permanent magnet synchronous motor is used in electric vehicle because of its characteristics.

A. Block Diagram:



Battery and super capacitor act as anenergy supplying devices to the permanent magnet synchronous motor during acceleration the energyfrom the battery is supplied to the motor to run the vehicle when deceleration the supercapacitor and battery together will supply the energy to the motor. The voltage source inverter is used to controller the speed of the motor at different driving characteristics.

B. Field oriented controller:

In ac motor the decoupling of stator and rotor is so what difficult. By using field oriented control, we can create the decoupling between torque and flux at constant current. The permanent magnet synchronous motor is controlled by using vector controller. In this controller we use different transformation for controlling. They are:
1.clark's transformation
2.park's transformation
3.inverse park's transformation
4.inverse Clark's transformation

C. Clark's transformation:

In this transformation **abc** is converted into $\boldsymbol{\alpha\beta}$ three phase rotating into two phase stationary.

$$\begin{matrix} ia \\ ib \\ ic \end{matrix} = \begin{matrix} cos\theta & sin\theta \\ \cos(\theta-120) & \sin(\theta-120) \\ \cos(\theta-240) & \sin(\theta-240) \end{matrix} \begin{matrix} i\alpha \\ i\beta \end{matrix}$$

Park's transformation: In this transformation $\boldsymbol{\alpha\beta}$ is converted into dqstationary to rotating

$$\begin{matrix} i\alpha \\ i\beta \end{matrix} = \begin{matrix} cos\theta & -sin\theta id \\ sin\theta & cos\theta\ iq \end{matrix}$$

D. Inverse park transformation:

$$\begin{matrix} id \\ iq \end{matrix} = \begin{matrix} \cos\theta & \sin\theta i\alpha \\ -\sin\theta & \cos\theta i\beta \end{matrix}$$

E. Inverse Clark's transformation:

In inverse Clark transform rotating two phase into three phase stationary.

$$\begin{matrix} id \\ iq \end{matrix} = \begin{matrix} cos\theta & \cos(\theta-120) & \cos(\theta-240) \\ sin\theta & \sin(\theta-120) & \sin(\theta-240) \end{matrix} \begin{matrix} ia \\ ib \\ ic \end{matrix}$$

II. CONTROL TECHNIQUE

A. Space vector pulse width modulation control technique of voltage source inverter:

- For controlling the voltage source inverter, we can implement sinusoidal pulse width modulation or space vector modulation using SPWM technique the speed and torque characteristics observed.

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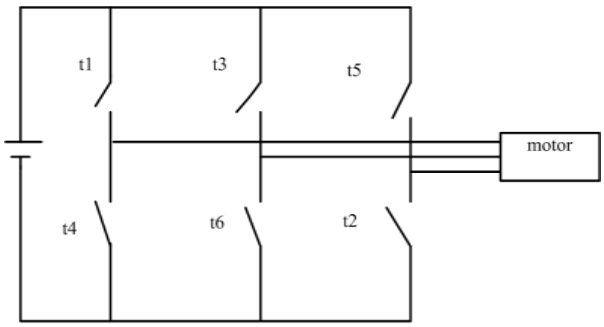
- The space vector is used as control technique for voltage source inverter at different angles the voltage source inverter is used for the motor to control at different loads.

Voltage source inverter is used to control the speed of motor at different characteristics.

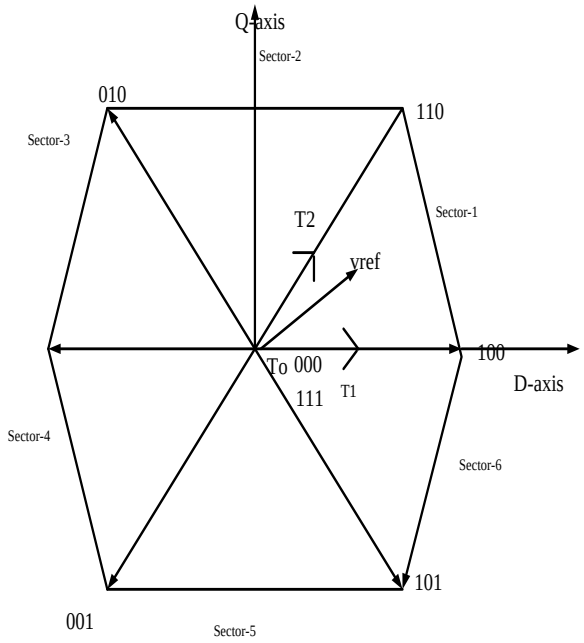
- By switching pluses at different modes.
- Voltage Source Inverters (VSI) have proven to be more efficient, cost effective, less space, faster dynamic response for rapid changes in speed or torque and be capable of running the motor without de-rating.
- Voltage source inverter operates as a rectifier during the braking mode and the rectified voltage boosted to charge the battery. Charging the phases depends on the switching sequence of inverter.

B. Voltage source inverter:



Voltage source inverter

C. Space vector pulse width modulation technique:



D. Voltage equations:

$$V_A = v_a + v_n$$

$$V_B = v_b + v_n$$

$$V_C = v_c + v_n$$

$$v_n = 1/3(V_A + V_B + V_C)$$

$$va = VA - 1/3(VA + VB + VC)$$

$$va = \frac{2}{3} * VA - \frac{1}{3} * VB - \frac{1}{3} * VC$$

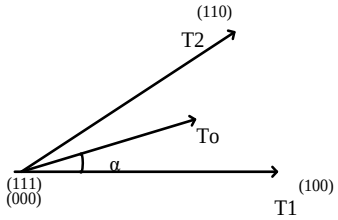
$$vb = VB - 1/3(VA + VB + VC)$$

$$vb = -\frac{1}{3} * VA + \frac{2}{3} * VB - \frac{1}{3} * VC$$

$$vc = VC - 1/3(VA + VB + VC)$$

$$vc = -\frac{1}{3} * VA - \frac{1}{3} * VB + \frac{2}{3} * VC$$

Sector-1:



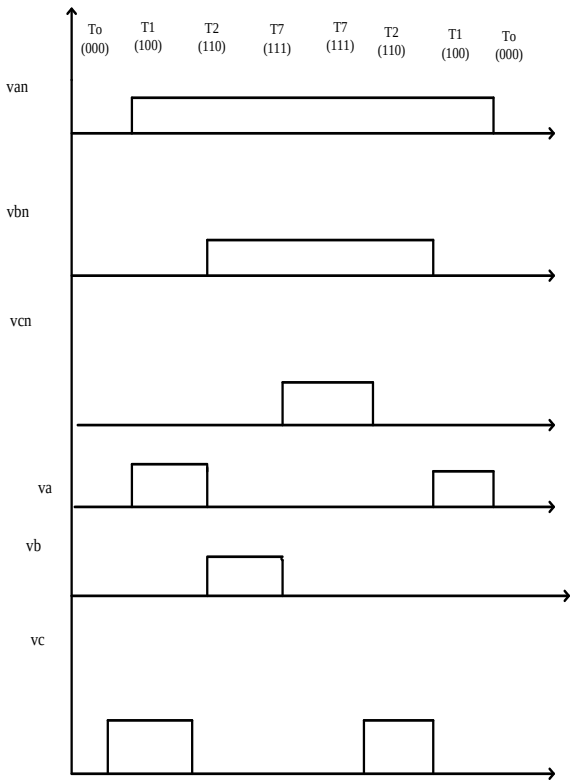
Switching states of Sector-1:

E. $T1=\sqrt{3}Ts\left(\frac{vs}{vdc}\right)\sin(\frac{n\pi}{3}-\boldsymbol{\alpha})$

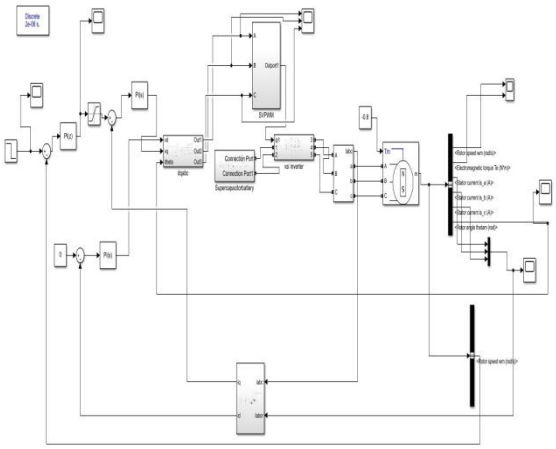
F. $T2=\sqrt{3}Ts\left(\frac{vs}{vdc}\right)\sin(\boldsymbol{\alpha}-(n-1)\pi/3)$

G. $To=Ts-(T1+T2)$

Voltage wave form of phase and line voltages:

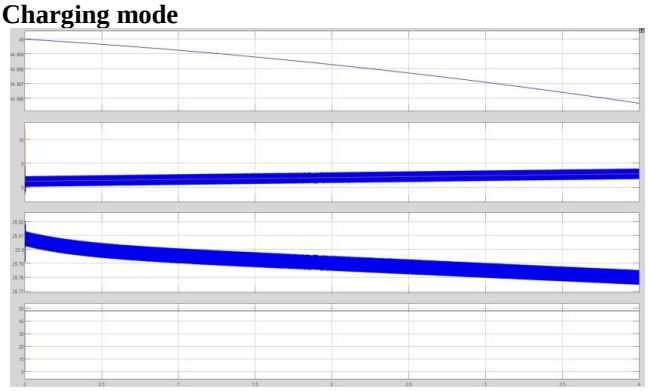


III. SIMULATION DIAGRAMS



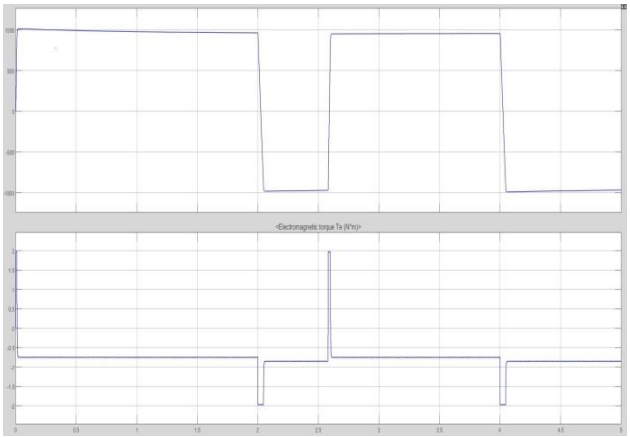
A. Battery outputs of charging and discharging mode:

Charging mode



Discharging mode

B. Output of four quadrants of PMSM mode:



C. Specification of the PMSM motor:

- Dc supply voltage:48volts
- Frequency :50Hz
- Number of poles :4
- Inertial(j) :0.0027kgm2
- Damping fraction:0.0004924Nm/(rad/s)
- Flux linkage:0.175wb
- Stator resistances:0.2ohms
- Inductances along d-axis :8.5e-3
- Inductances along q-axis:8.5e-3
- Nominal voltage:24
- Rated capacity:50(Ah)
- Rated capacitance:166.67
- Rated voltage:48
- Number of series capacitors:18
- Number of parallel capacitor:1

IV. CONCLUSION

Permanent magnet synchronous motor is gaining more and more attention due to its high efficiency and torque inertia ratio. PMSM motor is replacing dc machines and induction motor because of its different characteristics. In electric vehicle PMSM is used in front wheel and induction motor is used in rear wheel. The permanent magnet synchronous motor is controlled by field oriented control technique using space vector control technique. PMSM motor is driven at different characteristics. In first quadrant operation both torque and speed are positive, in second quadrant operation torque is negative and speed is positive, in third quadrant operation both torque and speed are negative and in four quadrant operation, torque is positive and speed is negative. In electric vehicle the motor should operate in different characteristics.

FUTURE SCOPE

Electric vehicle is the one which does not affect environment it is zero emission compare to internal combustion engines the EV is useful and many advantages are present in ev and it good for humans also. The motor should operate at different mode without failure of the energy supply to the vehicle should be supplied by both hybrid energy storage systems the four-quadrant operation of motor. Electric vehicle should be advantage to the environment and effect of dangerous gases into nature is reduced and the upcoming future generation is saved and the usage of fuel consumption is reduced and cost of the fuel also decreases. In future, the development of electric vehicle is to develop the battery with easily replacement if any failure occur and the cost of super capacitor should also be reduced and the capacity of the energy capability should increase the motor should also be capable to run efficiently at any condition. So the upcoming future should have the bright future to use electric vehicle

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